

Summary Report  
NOAA Great Lakes Environmental Research Laboratory Science  
Review

August 24-27, 2021



**Review Panel**

Ms. Sandra Eberts – U.S. Geological Survey, Chair  
Dr. Jeff Arnold – U.S. Army Corps of Engineers  
Ms. Jennifer Lacey – U.S. Geological Survey  
Dr. Rick Luettich – University of North Carolina Chapel Hill  
Dr. Ora Johannsson – University of British Columbia  
Dr. Catherine O'Reilly – Illinois State University  
Dr. Edoardo Sarda – Lake Superior State University  
Dr. Ram Yerubandi – Environment and Climate Change Canada



## Overview

National Oceanic and Atmospheric Administration (NOAA), Office of Oceanic and Atmospheric Research (OAR) laboratory science reviews are conducted every five years to evaluate the quality, relevance, and performance of research conducted in OAR laboratories. The Great Lakes Environmental Research Laboratory (GLERL) science review took place virtually from August 24<sup>th</sup> through August 27<sup>th</sup>, 2021. The scope of the review included three research themes, (1) Observing Systems and Advanced Technology (OSAT), (2) Ecosystems Dynamics (ECODYN), and (3) Integrated Physical and Ecological Modeling and Forecasting (IPEMF).

Prior to the review, the review panel was furnished with web access to resources that provided context for the review (for example, strategic planning documents; performance indicators; summary of prior science review and responses). The panel also watched pre-recorded overview and theme presentations. Panelists learned about GLERL's vision, mission, core competencies, facilities, workforce, funding/ budget, research leadership and planning, observing systems, scientific and engineering research and development, and research transition. Sessions during the review itself primarily focused on interactive questions and discussions, inclusive of discussions with internal and external stakeholders.

The review panel was impressed by the amount of work that went into preparing the resources necessary for the panel to complete its review. We thank all who were involved. The panel also was impressed with the GLERL leadership and the science that was presented. We congratulate all for their many accomplishments over the last 5 years (2016-2020).

As requested by the NOAA OAR Strategic Management Team review coordinators, panel consensus was not a goal for this review. Rather, each panel member individually evaluated one or more research themes and provided an overall rating for that theme(s), along with ratings for the quality, relevance, and performance of the theme. Two panelists with relevant backgrounds were assigned to each theme to ensure adequate coverage, but all panelists were encouraged to evaluate any theme they felt qualified to review. As a result, the OSAT and ECODYN themes each received feedback from five panelists, whereas the IPEMF theme received feedback from three panelists (Table 1).

The Review Panel Chair summarized all panelist feedback in the report sections that follow. The first section summarizes laboratory-wide findings and recommendations. The next three sections summarize comments and recommendations by research theme. The final report section succinctly summarizes all specific and actionable recommendations.

Table 1. Summary of the GLERL review panel ratings on program Quality (Q), Relevance (R), Performance (P) and Overall (O) for the Observing Systems and Advanced Technology (OSAT), Ecosystems Dynamics (ECODYN), and Integrated Physical and Ecological Modeling and Forecasting (IPEMF) research themes.

Reviewer		Research Areas													
		OSAT					EcoDyn					IPEMF			
		Q	R	P	O		Q	R	P	O		Q	R	P	O
Dr. Jeff Arnold		S	EE	S	S		EE	S	S	S		S	S	S	S
Ms. Jennifer Lacey		EE	HP	EE	EE										
Dr. Rick Luettich		EE	HP	EE	EE							HP	HP	HP	HP
Dr. Ora Johannsson							EE	EE	EE	EE					
Dr. Catherine O-Reilly							EE	EE	S	EE					
Dr. Edoardo Sarda		S	HP	S	S		EE	EE	EE	EE					
Dr. Ram Yerubandi		S	EE	S	S		EE	S	EE	EE		EE	EE	EE	EE

HP – Highest Performance

EE – Exceeds Expectations

S – Satisfactory

## Summary of Laboratory-wide Findings and Recommendations

NOAA’s GLERL conducts research to understand and predict the Great Lakes and coastal ecosystems; develop technology to improve NOAA science, service, and stewardship; and transition the results so they are useful to society. Overall, the review panel was impressed with the GLERL leadership and the Lab’s very talented and motivated workforce.

Panelists found that GLERL’s Director, Deborah Lee, has gone to great lengths to create a cohesive, well informed, and integrative science culture. Projects often span the capabilities of the three research themes, and they all relate back to the data repository and communications sections. Communications are based on regular, frequent meetings. Director Lee brought a well-honed planning process (Annual Execution Plan process) to the Lab that helps ensure the right projects are funded and the necessary infrastructure and resources are available when needed.

The bibliometrics for GLERL are very impressive, including the breadth and depth of the publications authored and co-authored by GLERL scientists, many of whom have been acknowledged through various awards. The Lab has strong stakeholder engagement and

interactions, a number of which depend on GLERL products for key decisions and operational use. Lab personnel also are engaged with their Canadian counterparts through the Great Lakes Water Quality Agreement (GLWQA), Lakewide Action and Management Plans (LAMPs), the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (Coordinating Committee), and other fora.

Nevertheless, there were some common themes that arose during the review, resulting in the lab-wide recommendations below.

1. Staff are concerned with the condition of Building 3 at the Lake Michigan Field Station in Muskegon, MI, resulting in a potential barrier to effective work. Panelists surmised that communications related to the field lab situation have been inadequate. Together, OAR and GLERL leadership should host a special all hands meeting to explain how NOAA facilities funds are procured and describe how OAR/ GLERL have been working to try and replace Building 3 at the Lake Michigan Field Station.

2. GLERL's addition of a Science Council, various committees, and routine lab-wide meetings since the last review indicate that leadership values communication. Yet, panelists heard from some entry-level and (or) newer staff that there remains a need for improved upward communication. GLERL leadership should continue to improve internal communications with a focus on opportunities for upward communication (for example, use of the Round Robin Method to encourage everyone to ask questions during meetings).

3. GLERL staff have high morale and pride in their work. GLERL leadership have made important hires and increased diversity since the last review—notable staffing accomplishments. The Lab has also lost several key staff. Panelists concluded that the laboratory is at or below a minimum level of personnel needed to maintain its scientific efforts. The use of contractors and Cooperative Institute for Great Lakes Research (CIGLR) employees helps the Lab meet its staffing needs, but resulting inequalities related to pay and upward mobility have drawbacks. GLERL leadership should develop a staffing plan that identifies the optimal mix of government, contractor and CIGLR staff to maximize retention and increase lab stability and then work toward that goal.

4. OAR's efforts to encourage NOAA to recognize the need for increased base funding in the President's budget request, OAR's creation of science portfolios to help identify and provide visibility for cross-lab science opportunities, and the GLERL leadership's efforts to procure outside funding to support new research (for example, Great Lakes Restoration Initiative funds) are commendable. Still, panelists are concerned about the relatively small amount of OAR base funding that is discretionary in nature and available to support science initiatives. Given GLERL's tight budget, it is important to identify the work GLERL definitely needs to be doing in the long-term and support it with base funding even if it means completing and (or) stopping some ongoing work.

5. Panelists were pleased with GLERL's efforts to improve science integration across the three research themes since the last review. These include the formation of the cross-theme Science Council comprised of principal investigators (PIs), and the focus on lab-wide strategic

objectives—as opposed to individual research theme strategic objectives—in the newly drafted GLERL Strategic Plan for 2021-2025. This new strategic plan includes details toward an implementation plan, but implementation planning is not yet complete. Panelists would like for GLERL to include the following in the 2021-2025 implementation plan:

- milestones across the entire duration of the strategic plan,
- timeframes for transitioning research to operations/ applications, or for ending work altogether, to facilitate starting higher priority work, and
- a graphical lab-wide roadmap(s) that identifies interdependencies among the research themes to help ensure lab-wide, as opposed to project-specific, science integration.

## **Findings and Recommendations by Research Theme**

### **Observing Systems and Advanced Technology**

GLERL’s Observing Systems and Advanced Technology (OSAT) branch conducts scientific and engineering research and development, identifies emerging observational infrastructure needs, and provides environmental observations and data throughout the Great Lakes. The review panel’s overall ratings for OSAT ranged from Satisfactory to Exceeds Expectations.

#### *Quality*

Panelists concluded that OSAT produces high quality data and products that are used by an extensive stakeholder community. The majority of OSAT’s work is focused on maintaining existing systems and/ or collecting data for the other research themes. About 10% of the work has a research emphasis with a goal of advancing technology. Some panelists were unsure if this is the right/ intended mix. Of note, OSAT co-hosted the Marine Technology Society (MTS) Buoy Workshop with the CIGLR and the Great Lakes Observing System (GLOS). It was the first ever Great Lakes hosted MTS workshop and attracted 115 attendees from around the world.

“OSAT group’s work is well aligned with NOAA’s OAR strategy as well as they have identified their role in broadly supporting data and uncrewed observations strategy. This group supports and collaborates well with other 2 science groups in meeting the requirements for understanding ecological dynamics and modelling. Over the years, GLERL’s operational satellite-based data products like temperature and ice cover have become very useful to the Great Lakes community. Since the last review, they have continued their technological developments in buoy systems, AUV [Autonomous Underwater Vehicle] based ESP [Environmental Sample Processor] etc. I also have a very high opinion of the vessels program which seems to be supporting NOAA’s interests well in the Great Lakes, although their focus is limited to Michigan and to an extent in other Great Lakes. Since the last review they replaced a retired scientist with a new remote sensing scientist, and with this I am hopeful that the research in this area will be continued. Except for this work, the rest of the OSAT work is more technical (not really research) in nature – assembling different sensors or buoys and other observing systems. We heard from the stakeholders that GLERL’s support is important in several themes and OSAT’s support in installing buoys or IT/communication and implementing monitoring networks and satellite data products are very important to them. It is difficult to assess the quality of research outputs as very few papers are led by this group, which is understandable given that their main role is supporting the other groups.”

“The data and products from OSAT appear to be high quality and heavily used by stakeholders. In particular the remote sensing observation products from CoastWatch and the [Experimental Lake Erie] Hypoxia Warning system were identified by stakeholders. The CPA-A [Color Producing Agent Algorithm] products being able to be adapted

to different stakeholders needs, appears to be a very unique and innovative approach. OSAT's hyperspectral research could be very beneficial, particularly if successful in utilizing drones. Although it is unclear why more drones are being added to the fleet when the technology has not been proven yet. The ReCON [Real-Time Coastal Observation Network] research and engineering has been proven for using high bandwidth observations, it is not clear how this will evolve or be utilized in the future."

"Significant partnerships with academia, other government organizations, and even commercial, such as Viking."

"In general, it seems like the people working in the area of OSAT hold high quality standards and have access to the necessary resources in terms of technology to perform their duties. However, it seems like most of the work conducted in the area of OSAT is not scientific research. Furthermore, it was reported that only 10% of the time was devoted to novel research in the area of OSAT. The rest of the time was devoted to maintaining existing systems operational and collecting data for research in other areas (e.g. ECODYN and modelling). When the OSAT group was asked to expand on some of the scientific research, they could only report one effort that's being led by a newly hired scientist."

"The OSAT group does high quality observing system work, much of which is routine but a portion of which pushes traditional data collection methods, e.g., the under-ice cabled observing system."

### *Relevance*

The panelists found OSAT activities to be in line with NOAA's key strategic goals and to Exceed Expectations or achieve Highest Performance. The data and products produced by OSAT are extremely relevant to many internal and external stakeholders, although it was generally agreed that the work is not appropriately balanced among the five lakes. The increased use of uncrewed systems was favored by the panelists and should enable OSAT to meet additional stakeholder needs, including needs related to winter data and associated products. Some panelists expressed hope that the focus on winter observations and research will help GLERL grow its base funding.

"OSAT's core activities are in line with NOAA's key strategic goals of supporting marine services and contributing to international collaborations like GOOS [Global Ocean Observing System] etc. Their ongoing hyperspectral and AUV based work is critical for HAB [Harmful Algal Bloom] tracking in Lake Erie, Michigan and Lake St. Clair. Their operations group is critical for maintaining buoys, platforms and data management i.e., real-time data communication through information portals such as GLOS [Great Lakes Observing System] and transmitting data through the NDBC [National Data Buoy Center] etc. Their work is directly relevant to coastal communities (for eg: Cleveland drinking water intake). Their vessel group is well placed to support activities in some of the Great Lakes, but their focus is highly regional with heavy emphasis on Lake Michigan."

"Several efforts are focused on NOAA's uncrewed strategy. Of particular note are the cable system for year around autonomous systems and the 3<sup>rd</sup> generation ESP in collaboration with MBARI [Monterey Bay Aquarium Research Institute]. Future strategies focus on acoustic measurement, autonomous vessels, and cabled systems. These technologies will largely be utilized for under ice monitoring. It is unclear the main stakeholders that are driving the focus on these measurements or how that was determined to be a top priority. DART [Deep-Ocean Assessment and Reporting of Tsunamis buoy], which directly supports NOAA's mission to protect life and property, could be another key area for OSAT."

"I understand the need for year-round (winter) measurements. GLERL is taking the lead on this, which is commendable. I am hoping that this, somehow will not diminish their capacity to work in spring and summer to monitor and report on HABs, Hypoxia etc."

"Although most of the work performed in the area of OSAT cannot be classified as scientific research, the data collected and the systems used to collect this data are extremely relevant to many stakeholders and other GLERL members."

## *Performance*

Panelists found OSAT to be effective in performing its core duties. There was some concern, however, regarding retention of scientists and engineers. More concerning was the finding that some staff fear there are safety concerns surrounding the Lake Michigan Field Station, although GLERL leadership assured the review panel that the facility is safe, albeit unpleasant. Such beliefs, however, could become a barrier to the team working effectively. The vessel fleet—the backbone of many operational measurements—also needs an influx of capital. Panelists learned that GLERL leadership has been pursuing funding for its fleet; specific plans for the fleet were not provided. Panelists heard that the process GLERL uses to formulate requirements for future data and technology is not uniformly known across its stakeholder community and is somewhat dependent on personal relationships; this latter observation is relevant to the other research themes as well.

“The OSAT group seemed effective in performing its duties and adequately involved in all necessary areas to conduct research and development. However, it was clear that the OSAT group faced challenges in retaining scientists and engineers, especially software engineers, due to reliance on personnel at the Cooperative Institute for Great Lakes Research (CIGLR), which has a relatively high turnover rate.”

“Some comments also implied that, even when equipment was available, the human resources required to utilize it were limited (e.g. personnel to operate a boat vs boats available).”

“There was mention of testing, diagnostics, and calibration of sensors, as well as quality control and assessment of the data, but very few specifics and no metrics were provided. The real-time data quality assessment process was described in detail and seems to be very thorough.”

“From my perspective, this group’s main goal of identifying observational infrastructure needs based on their collaborations with other groups and deploying boats and instrumentation (routine and emerging) is met well. They also provide data dissemination through different platforms. The amount of technology transfer to operations from this group is impressive. The Lake Michigan Field station operates vessels of different sizes and it is one of the critical parts of GLERL’s successful field campaigns, but we heard that this facility is in renovations and some staff expressed safety and other concerns.”

“The vessel fleet is a backbone to many operational measurements. However, there were no future or evolving plans for the fleet or upgrades presented.”

“The process GLERL uses to formulate user requirements is not well known outside of the NOAA users [e.g. not understood by external stakeholders]. Most of the process seems to be dependent on personal relationships.”

## *Actionable Recommendations*

1. Opportunities to pursue independent research appears to be more limited within the OSAT theme compared with the ECODYN and IPEMF themes. That said, the OSAT group does frequently apply existing technologies in novel ways (for example, the use of drones to tell autonomous surface vehicles where to go next) and these applications are worthy of publication. *If pushing the envelope with regard to observing systems is important, GLERL leadership should clarify the role of curiosity driven research within OSAT and follow through with an appropriate level of support.*

“Overall, the OSAT group has been able to play an active role in supporting NOAA’s mission and value to the Nation, however it is unclear if this includes curiosity driven research, or simply funding driven work. I would

encourage allocating time for scientists to pursue their own interest/curiosity driven research that aligns with NOAA's mission."

"I know this branch is created as a research group due to one of the recommendations about 10 y ago, but as mentioned above in my comments, except for one researcher on remote sensing, most of the work is directed to services and not really research or new sensors or technology development. I believe it may become important to demonstrate that this group really needs to be research driven or current model (mostly) providing services."

2. Demonstrating a winter and under-ice ecosystem observational capacity and developing a Great Lakes meteotsunami detection, forecast, and warning capability are important new directions for OSAT. These and other observing systems should not be limited to a subset of the lakes. Rather, OSAT should establish observing systems more uniformly across all five lakes.

"The main areas of improvement involve focusing data collection during the winter months and in all five lakes (instead of focusing on Lake Erie)."

"Building upon the award-winning ice type algorithm work and expanding for ice thickness and ice forecasts would be beneficial."

"There were opportunities identified by stakeholders that could be addressed. One area is to broaden monitoring and research to the entire five lake system."

3. The process for communicating requirements to guide GLERL/ OSAT activities is informal and iterative. GLERL/ OSAT should develop a formal process for internal and external stakeholders to communicate future data and technology requirements and share the process with stakeholders.

"OSAT currently works with PIs to evolve sensor technology to meet GLERL research needs, but that process did not seem to be well defined. A more formal method to understand scientific measurements needed and the gaps that exist with what is currently being produced could help determine future data and technology direction. There doesn't seem to be a direct flow from research requirements to sensor requirements, it is a more iterative process, which is likely not efficient."

"It would be beneficial to engage in regular external stakeholder meetings and formulate a communication strategy with them [regarding requirements process]."

### **Ecosystems Dynamics**

The Ecosystem Dynamics (ECODYN) branch strives to monitor, analyze, understand, and predict changes in Great Lakes and coastal ecosystems to strengthen capacity for managing water quality, fisheries, invasive species, and ecosystem health. The review panel's overall ratings for ECODYN ranged from Satisfactory to Exceeds Expectations.

#### *Quality*

All panelists rated ECODYN's quality as Exceeding Expectations. Awards were won by all scientists present for the review, including a lifetime achievement award for the Program Leader. ECODYN research scientists each belong to several scientific societies, review for multiple journals, and co-author several papers per year. The ECODYN group has mentored many postdocs, PhD candidates, master's candidates, summer fellows, undergraduates, and others. ECODYN is well integrated into the Great Lakes scientific community and contributes to several boards. ECODYN conducts exceptional work in numerous areas (for example, transcriptomics



on Microcystis). However, some panelists were concerned that maintaining projects despite fewer personnel could come at the cost of quality.

“The Ecosystem dynamics group has been outputting a high number of high relevance publications over the years to support its research mission. The high quality of the work and data collected is also available thanks to the OSAT group resources.”

“Good number of publications in reputed journals, several citations of past research, but also some for the current papers, which is a good sign. There are quite a few well-established scientists, and naturally their participation in several boards will have influence in the Great Lakes scientific community. Since the last review, I think they have hired new staff (replaced folks who left) and I look forward to their publications.”

“The awards received by GLERL scientists from NOAA and the President attest to the scientific merit and goal directedness of the ECODYN research. Awards were won by all scientists present during the full review period and by two Biologists – for different work in different years. Hank Vanderploeg was also awarded the Life-Time Achievement Award from the International Association for Great Lakes Research. This is a prestigious award and much deserved by Hank.”

“ECODYN research scientists each belong to several scientific societies, review for multiple journals (an average of 10 each) and co-author an average of 3+ papers a year. Four of the scientists hold positions on LaMP [Lakewide Management Plan] working groups. On occasion, they might also hold an editorship position or organize a special issue of a journal. ECODYN scientists are also strongly involved in mentoring: 4 post-docs, 15 PhD candidates, 12 Masters Candidates, 24 Summer Fellows, 11 undergraduates and 8 others have been mentored over the period under review. That is the equivalent of guiding 13.7 extra personnel/scientists each year. At some unspecified level, the scientists are also involved in community outreach.”

“Scientific collaboration is relatively broad. There is good diversity in who GLERL staff are co-authoring with, both internally and externally. People appear to be interacting across the branches and also have strong external collaborations. This bodes well for the generation of new ideas within GLERL and the sense of being part of a team. The more senior PIs have a higher number of publications, including leading them, underscoring their position as more established scientists. The journals are of high quality and widely read within the discipline. ... I was a bit surprised that some staff had not been first authors on any publications, and I hope they are provided with opportunities and/or mentorship needed to lead.”

“ECODYN scientists and biologists worked collaboratively with others from a wide variety of institutions around the Great Lakes and in some cases with personnel from other regions (e.g. Gulf of Mexico work). This indicates that they are well integrated into the Great Lakes Scientific community and can both lead and learn from the community, raising the overall level of scientific research on the Great Lakes. Much of this collaboration has been fostered by NOAA’s support of CIGLR and of specific research programs (Great Lakes Restoration Initiative), and by the CSMI [Cooperative Science and Monitoring Initiative] program run by the USEPA [U.S. Environmental Protection Agency] and ECCC [Environment and Climate Change Canada].”

“Although I thought their long-term research (LTR) is somewhat becoming routine monitoring, because of the key scientists it is still producing high quality publications. This data will be useful for developing and testing ecological models in Lake Michigan, and hopefully that science will be transmittable to other lakes. Because most of the staff work on Lake Michigan LTR, there are few opportunities for cross-border collaborations [related to long-term research].”

“GLERL’s research is on the leading edge of science especially with respect to understanding HABs, ice dynamics, and ecological forecasting.”

“One of the many strengths of GLERL, including the ECODYN group, is the goal of modelling and predicting Great Lakes systems. The hydrodynamic, hypoxia, HABs and ice forecasting models are all essential to the success of the upcoming foodweb models. The extension of these models into the nearshore using irregular, small unit-areas is a real advancement in our potential to understand nearshore-offshore coupling. And the incorporation of seasonally forced, vertical structure greatly increases the ability of the models to depict present and future conditions in the

lakes. These models give us a tool with which to develop understanding and to test this understanding (hypotheses) against reality. I like the care, which is taken to parameterize the biological models, obtaining in-house process estimates for system/species specific parameters which increases the robustness of the models. I am very excited about the future science and understanding that will come from these foodweb models.”

“I appreciate that there has been an effort to develop a program that is aligned with the overall omics mission of NOAA. There does seem to be a reasonable plan in place for this work at GLERL, but I am not entirely sure of its value at this point.”

“Exceptional work done by ECODYN:

- Transcriptomics of Microcystis and culturing of native varieties
- HABs behavior in the HABs forecasting model
- Coupling hydrodynamic and foodweb models to investigate questions of nutrient levels and climate change on primary productivity (chlorophyll a) in Lake Michigan
- Modelling of suitable habitat of Invasive carp
- Construction of the tipping point model to assist communities with ecologically-relevant decision making”

“Areas of research are balanced with publications on invasive species (30), foodweb dynamics (21), fisheries (14), HABs (6), and nutrient impacts (9). Davis papers on HABS (8) and hypoxia (1) were not included in these counts.”

“Manuscripts were published in good journals; however, none were published in the highest-ranking journals (Nature and Science). It is noted that the Rowe (+ 4 other EcoDyn scientists) et al. 2017 paper in Limnology and Oceanography has received 42 citations by 2021 – one of the 20 best cited articles in GLERL.”

“Current research quality is very solid but looming on the margins is a potential drop in quality. What they are currently doing does not seem to allow for deeper engagement with their work. There seems to be a trend towards quantity (e.g., maintaining projects despite fewer personnel, engaging in projects because they bring in funding) that may soon come at the cost of quality. The expertise of these scientists may be spread too thin for them to have the time for reflection and the interactions/conversations that are necessary to produce the highest quality outcomes.”

### *Relevance*

Panelists who reviewed this research theme found ECODYN’s work to be aligned with NOAA’s strategic goals and were pleased to learn of research that addresses both current and (or) future issues. They found stakeholders to be very complimentary of ECODYN—an indication that ECODYN is addressing ecologically, economically, and societally important problems. For example, fisheries managers use ECODYN’s Long-Term Research (LTR) program data to help stay abreast of environmental and lower trophic level trends. One panelist described the long-term datasets as the backbone for the emergence of new research questions. Panelists also noted the importance of ECODYN’s varied modeling work and recognized areas in which ECODYN scientists are leaders in their field (for example, ecological forecasting for water quality).

“GLERL/ECODYN addresses NOAA goals to understand and predict change in aquatic systems, to ‘help’ conserve and manage aquatic ecosystems and resources, and to make that information available. The OAR goals are more specific but align with the NOAA goals: explore, detect change, forecast, and produce innovative science/solutions. These goals are accomplished within ECODYN by increasing understanding of the Great Lakes systems, through long-term monitoring, experimentation, process assessments, modelling and targeted studies. The data and understanding are disseminated through data repositories available to the public, scientific publications, participation on national and international committees and working groups which guide the rehabilitation of the Great Lakes under the Great Lakes Water Quality Agreement (regarding nutrients/hypoxia/HABS, invasive species and ecosystem health), mentoring of students and exchanges with the public.”

“I think their research is well aligned with most of the NOAA’s strategic goals. The staff is not only conducting research on present issues, but on the lookout for future issues like for e.g.: invasive species effects on food webs etc.”

“Most or all of ECODYN work addresses stakeholder needs. ECODYN stakeholders include the Great Lakes Fishery Commission Lake Managers (research questions linking the lower foodweb with larval fish success etc), Lake Erie water intake managers (hypoxia and HABs forecast modelling), municipalities (Tipping Point Planner, education of students and the public), IJC (activities under the Great Lakes Water Quality Agreement which include invasive species [Invasive carp (habitat modelling), dreissenids ( distribution, and growth leading to bioenergetic modelling)], nutrient investigations (for HABs and Lake Michigan foodweb], working with the LaMPs [e.g. longterm monitoring of the lower food web in Lake Michigan]), and National Parks (bottom mapping).”

“ECODYN stakeholders are very complementary of the role GLERL (and ECODYN) have made in addressing their needs. They noted that GLERL’s programs are responsive to stakeholder needs, include stakeholder input from a very early stage, and are never stagnant, but always trying new things. Stakeholders are looking forward to continued involvement and wish increased collaboration (Fisheries Managers). This means that GLERL and ECODYN are addressing ecologically, economically and societally important problems.”

“In many cases the data and models from this group are important for GL ecosystem management. Stakeholder comments were informative, I am not sure how feasible it is to do this, but a few stakeholders would like to speed up the process of hypoxia forecasting tools to operations.”

“Data products are services that are considered high quality and widely used. GLERL staff have been responsive to feedback and stakeholders generally praised staff and their work. Stakeholders seem to be collaborative partners in tool development, tools are chosen based on stakeholder needs and adjusted in response to feedback. At the same time, GLERL does see itself as being driven by the research questions and by stake-holder needs.”

“The LTR [Long-Term Research] program directly addresses NOAA’s second goal of detecting change in the environment and is a great asset to GLERL scientists. The data are frequently used to assess change, nearshore-offshore patterns and populate models. At least 16 publications during the review period were authored or co-authored by Steve Pothoven, the scientist in charge of the LTR Program. The LTR data are passed on to the Lake Michigan LaMP/Fisheries Managers each year to help them keep abreast of environmental and lower trophic level trends. The LTR data also provide modellers with a database to develop foodweb-based models and to test ideas. Other research on nearshore/offshore gradients, foodweb structure, and impacts of invasive species are frequently layered on top of the LTR program. Without the base program, these other studies would not have a platform on the lake, but more importantly, would not have an extensive data set to place their findings in context. LTR programs are set up to detect change. Sometimes the change is expected as in response to changes in nutrient loadings, or the advancement of climate change, and at other times it is unexpected, as in invasive species, where the impact of the change on the foodweb needs to be known rapidly because it may affect fisheries and other economic interests.”

“GLERL’s major research strengths lie in the long-term monitoring program and in ecological forecasting, as well as the work on ice dynamics and winter limnology. GLERL has really initiated and led the development of ecological forecasting for water quality from a nascent stage to operations and could be considered a leader in this field. These programs are intertwined in some respects (models need long-term datasets for development and validation). The long-term datasets provide the backbone for the emergence of new research questions. Other research may build off these core components or be related to collaborators interest and stakeholder needs – this work provides value for stakeholders but primarily at the local/regional scale.”

“ECODYN contributed to the development of the ‘Tipping Point Planner’ to guide regional municipalities in making ecologically beneficial land use decisions which will help them locally, but also help the Great Lakes. Good land management leads to improved physical, chemical and biological conditions in the adjacent lake. ECODYN has also substantially contributed to the HAB Forecast Model, and with its recent omics work and studies of Microcystis varieties is poised to make major contributions to modelling the timing and presence of toxins. Both models are hugely beneficial to society. The former is now held by Purdue University and has been accessed thousands of

times (Sea Grant stakeholder). The latter model is in constant use in Lake Erie by the water intake corporations to allow them to be prepared to treat the source water appropriately and prevent periods of water intake closures.

Other modelling efforts have less direct effects but are also critical and respond to the needs of the Great Lakes Water Quality Agreement. ECODYN has contributed to revised assessments of Invasive carp habitat in Lakes Michigan and Erie. These data contribute to the growing evidence that continue to push authorities to prevent access of these carp to the Great Lakes and to better understand the consequences if they do invade. ECODYN has also led the scientific field developing a combined foodweb-hydrological model for Lake Michigan. Using this model, they investigated the role of nutrients, climate change and hydrology on the planktonic foodweb, assessing whether increased nutrient loading in Lake Michigan might be beneficial in the future. This is a question of interest to the Lake Michigan LaMP and Fisheries Agencies, as well as to downstream regions of the Great Lakes that are battling declines in plankton populations and fish stocks coincident with invasive species, and the increased problems with HABs in shallower, more nutrient rich regions. The inshore and nearshore-offshore gradients have been better parameterized in these models due to work during the 2016-2020 review period. The present work on parameterizing quagga mussel growth rates across depths and seasonal is in preparation for development of bioenergetic models for quagga mussels (majority of benthic biomass) for improved temporal and spatial input of benthic energy movement in the foodweb models (as well as for better understanding of quagga mussel biology and nutrient flow across the nearshore-offshore gradient)."

"It was really nice to see some interdisciplinary work being done, such as the social science side of hypoxia. While it can be time consuming to collaborate across disciplines, these inputs can provide critical insights that allow scientific results to be more successfully applied toward environmental management and pay off in the long run."

"Researchers' interests are too varied, for e.g.: fish recruitment and invasive species to physical-biological mechanistic modelling. This is not necessarily bad, but not sure how the research is prioritized to address key GL ecological questions."

"Some research appears to be historic (or legacy and LTER) which is understandable given that it is led by senior researchers. I am glad to see that the data generated by them is used extensively, and publications are well-cited. One of my main concerns is that significant resources are used for this work and it did not look feasible to support some more interesting/exploratory research by others."

### *Performance*

Panelists felt the ECODYN leadership was successful in achieving most goals in GLERL's 2016-2020 Strategic Plan and addressing recommendations from the previous (2016) science review. They found ECODYN scientists to be very knowledgeable and efficient based on the small number of employees compared with the wide range of activities and accomplishments. Panelists had some concern, however, that people are spread thin. A few panelists wondered whether and how PIs synthesize findings across projects to address overarching research questions. Panelists also were unclear whether the reliance on external funding (for example, GLRI) affects science directions and science synthesis. Several panelists were complimentary of efforts to disseminate knowledge and make data public, although one panelist questioned whether the value of ECODYN's work is consistently visible.

"The Director's office provides effective scientific leadership to and interaction with NOAA and the external community within the Great Lakes through its participation on important scientific committees and boards. The Director, herself, sits on 20 high level boards providing insight to other institutions and direction to GLERL. Five of the 6 scientists in ECODYN also sit on a total of 16 boards/panels/working groups/committees providing input and bringing back information."

“All the scientists involved in this group are very knowledgeable and capable of identifying the most relevant tools and information to output high quality research. The group also seemed very connected, as it is composed of scientists working together for the same common mission.”

“I liked the group lead’s presentation and everyone, particularly new PIs, coming together in support of their fearless leader is interesting.”

“Staff were passionate about being part of GLERL and seemed willing to take on extra tasks in the short run. PIs felt they had ample opportunities to develop their own research project areas. Although there was not a formal mentoring project specifically at GLERL, there are mentoring opportunities within NOAA that are supported by GLERL leadership. People feel like they get feedback and informal mentoring from their supervisors.”

“ECODYN leadership has ensured the accomplishment of most of the goals in the 2016 5-yr plan. ... although covid slowed down progress on some:

- Sections ‘A, C and F’; work completed or in good progress. Delays due to covid.
- Section ‘B’: although MOCNESS [Multiple Opening and Closing Environmental Sensing System] equipment was added to spatial cruises, no mention of fish acoustics, or other equipment or sensor updates were mentioned in the GLERL 2016 implementation plan update. Were these equipment added to spatial cruises? On the other hand, the lab has added ‘omics’ technology to its studies with great success particularly in the study of HABS.
- Lake Huron CSMI – results provided are all for Lake Michigan, there was no mention of GLERL’s participation in Lake Huron CSMI. The lab has been ‘criticized for not working more in the other Great Lakes’. What work was done by ECODYN in the Lake Huron CSMI?
- Foodweb structure and function, again, was only published for Lake Michigan although Lake Huron is mentioned in the planning document. Was this delayed due to covid restrictions?
- Section ‘D’. Mortality rates not included yet in the HAB tracker model. Is this true? important?
- In addition, GLERL has addressed recommendations from the previous scientific review.”

“They [ECODYN scientists] have also accomplished other goals adopted during the time period as demands became known or opportunities arose. Such an example is the Tipping Point Planner. As mentioned above, the group has earned several prestigious awards from NOAA, published numerous papers and mentored many students. These are all signs of good leadership. The group lost Dr. Davis and recently gained his replacement, Dr. Errera, which may have slowed some of the HABS work.”

“ECODYN researchers work across a range of projects, addressing NOAA/GLERL objectives within the Great Lakes. Given the low number of employees and wide-range of activities and accomplishments of the ECODYN personnel, they must be working efficiently. Their awards and the praise from their stakeholders also indicate that they are working effectively.”

“Overall, ECODYN seems to be dealing as well as they can with the projects that they are involved in given the shortfall of staff/budget. In that respect they exceed expectations given the context. It seems like they have more tasks to do than time to do them. GLERL seemed to be involved in a lot of different projects where they are not the leaders? It seems that people were spread thin across diverse tasks, and project management and tracking must be challenging.”

“My main comment will be that the projects and themes are a bit all over the place, individually each PI’s research seems to be exceptional, but I struggled to understand how the team is synthesizing this research. They are all contributing bits and pieces to the understanding of Great Lakes ecosystem dynamics, but what is it that they collectively want to inform the GL community? This could also be due to heavy reliance on external funding for some of the work (for eg: GLRI). I also felt the research is limited to one or two Great Lakes only.”

“[ECODYN leadership needs] better communication with scientists on how work direction fits with the mandate.”

“The NOAA base funding provides 18-19% of the ECODYN science research budget. ECODYN researchers have been very effective at leveraging other funds. The majority of extra funds come from the NOAA Restoration Initiative [Great Lakes Restoration Initiative (GLRI)?]. It should also be noted that the Director has gone to great lengths to try to increase funding to the GLERL lab both for scientific work but also to restore the building(s) at the Muskegon [Lake Michigan] field lab. The science accomplished by ECODYN personnel is greatly increased by these many collaborative partnerships, particularly through the NOAA’s Cooperative Institute for Great Lakes Research institution [CIGLR] and the associated universities– to witness, the extent of multi-authored papers they produce with CIGLR and non-NOAA co-authors.”

“I was concerned about how staff based at the field station are integrated into the broader GLERL. Travel between the two locations was described as being sufficient to ensure for timely transfer of equipment and samples. One of the staff goes back and forth only every other month and said, ‘they make it work’.”

“Clearly, the upgrading of the field station is critical for both the short and long-term success of GLERL. The efforts to acquire funding for this seem to be above and beyond what should be necessary and are likely distracting GLERL leadership from other tasks. It is shameful that the federal government does not facilitate maintenance of infrastructure that their employees depend on to do their jobs. In addition to the field station, other infrastructure that it is important to maintain are regular IT equipment upgrades, including providing time for staff to receive training that keeps them at the forefront of IT.”

“Discussions with new employees revealed ... They didn’t understand the issues with trying to fix the laboratory in Muskegon, [MI].”

“The Union seems to be invaluable for getting information disseminated to lower-level staff.”

“I felt that ECODYN could be better integrated into the larger scientific community. While I recognize that there are no really comparable lake systems in terms of scale, there are opportunities to translate the work being done at GLERL to smaller scales or to other large lakes that face similar issues. Many of the other large lakes of the world are not in US territory, so this is somewhat outside the mission of GLERL, yet at the same time many of the issues that GLERL is working on are the same issues being faced by the African Great Lakes, for example (invasive species, oil and gas leaks, climate warming) and by Lake Baikal (ice dynamics). It would be great if the expertise at GLERL could be applied more broadly through collaborations at these other locations. There is a push to develop a buoy-based environmental monitoring program in the East African Rift Lakes – GLERL may have some of the most experience in the world with respect to such a monitoring program. While early-career staff said they felt integrated into the broader community and were encouraged to do things such as attend conferences, be on thesis committees, etc. there actually was not as much engagement in relevant disciplinary societies and conference as I would expect and hope for, if GLERL wants to remain well-networked with the aquatic sciences. Some early-career staff specifically noted that their invitations to participate in various professional activities was a factor of the connections they had made before starting at GLERL. Unfortunately, this probably means that GLERL’s work may be less well-known. I note that there is some funding available for travel and training, so maybe the issue is a lack of time?”

“GLERL (and ECODYN) makes great efforts to disseminate its knowledge, as mentioned above. The data and understanding are disseminated through data repositories available to the public, Sea Grant outreach programs, scientific publications, participation on national and international committees and working groups which guide the rehabilitation of the Great Lakes under the Great Lakes Water Quality Agreement (regarding nutrients/hypoxia/HABS, invasive species and ecosystem health), mentoring of students and exchanges with the public.”

“Challenges with getting the data made public are a widespread issue in science, especially with historical data, and it was nice to see that there were actual plans and personnel in place to help facilitate this.”

“It was fantastic to hear that there were efforts to engage with native American communities and this work should be encouraged and supported.”

“Staying connected and communicating effectively to the stakeholders is critical. Some stakeholders wanted more engagement with GLERL with respect to fisheries. Although GLERL does have a clearly defined research role in fisheries, stakeholders wanted GLERL to be more present in discussions about fisheries because they felt GLERL could provide valuable input. There may be a need to better coordinate fisheries roles among the various agencies and stakeholders and to clarify these roles with stakeholders.”

“It wasn’t clear that management was aware of some of the issues with the transition to operations. I wonder if this is a place where things sort of fall off the responsibilities list– who at GLERL is actually responsible and accountable for making sure this happens?”

“The stakeholders were very complimentary of the quality of work done by ECODYN and the contributions of GLERL/ ECODYN to their science and responsibilities. In the case of the Fishery Commission, they wished to see more GLERL researchers with ties to Fisheries Managers. With the future development of food web models for each of the Great Lakes, I expect there will be more interaction between fisheries people and GLERL researchers.

“... the stakeholders were complimentary of the process of early stakeholder involvement, how it led to better fits to stakeholder needs and better communication between stakeholders, operators and research scientists. A detailed development plan with milestones and commitments is drawn up for work for/with stakeholders from other government sections and municipalities. One stakeholder indicated that the rollover of products from GLERL R&D to his group was not happening. Delays could have a number of reasons including the transfer acceptance of the product by NOS. That stakeholder also thought that scientists do a project and move on. This suggests that better communication on reasons for delay and that follow up on the working of the product is needed. However, the stakeholder also needs to understand that it is necessary that scientists work on a project and then move on to the next.”

“Value of their programs is not consistently visible. I had questions about the science communication, it wasn’t clear what their approach and strategies were and there was some suggestion that they could better leverage CIGLR for some of this. The ECODYN website could be slightly updated to highlight the strengths of their work by including some of their findings. This might be especially important for the long-term monitoring program [https://www.glerl.noaa.gov/res/Programs/eco\\_dyn/eco\\_dyn.html](https://www.glerl.noaa.gov/res/Programs/eco_dyn/eco_dyn.html).”

“There was also the suggestion that Sea Grant could undertake more of the outreach work for GLERL.”

### *Actionable Recommendations*

1. The ECODYN group has a long history of working in Lake Michigan due to early eutrophication of the lake. Their long-term ecological observations and targeted fundamental research in Lake Michigan have served to advance understanding of ecosystem structure and function in the Great Lakes. This work can’t be replicated throughout the lakes because such study requires 24-hour data over long periods of time. Still, several panelists felt that ECODYN should initiate more collaborations with Canadian scientists (and others outside the Great Lakes) to broaden the scope of the research performed.

“As compared to OSAT, it seemed like a lot more research related activities were performed. Most of these activities required the support, the technology and the data provided by the OSAT group. The main recommendation I have is to strengthen the collaboration with Canada on projects involving the bordering Great Lakes. This collaboration can be in the form of grant writing/ funding, research, data collection, data analysis and publications. Considering that this is not my area of expertise, the ECODYN group presented research that seemed relevant and of high quality.”

“The work performed by this group is very much aligned with NOAA’s mission and it’s essential for many stakeholders, as it was highlighted during the discussions. It would be important to strengthen international collaborations, especially with Canada, to broaden the scope of the research performed.”

“Encourage more deeper collaborations with academia and Canada- many projects in this branch will benefit with external research that is being done in the Great Lakes.”

“Determine if GLERL can/should participate in some of the recently emerging networks of people in freshwater science – GLEON [Global Lake Ecological Observatory Network] and Ecological Forecasting. GLERL could bring a lot of expertise and datasets to the science being done collaboratively through these networks, which would also raise their international profile. In addition, this keeps GLERL scientists interacting with the broader scientific community and helps them stay abreast of new developments rather than learning of them through publication, which can appear 2-4 years after the work was really done.”

2. The panelists were impressed with ECODYN’s portfolio of work. Some panelists, however, were concerned that the group’s research interests are too varied and questioned how research is prioritized to ensure that key Great Lakes ecological questions are addressed. Others were concerned about research topics that are not being addressed but should be. Do PIs pursue research that is most likely to generate funding but may have limited relevance to the larger issues across the lakes, owing to the considerable amount of base funding the LTR consumes? *ECODYN should develop a long-term research plan (5-10 years) that includes key research questions and create a priority plan within that plan to inform near-term research investments; planning should be inclusive of all Great Lakes.*

“Currently, most of the effort also goes into the LTR, as that is where most of the base budget is. This seems to create a situation where PIs have to get involved in other projects for the funding support, but these projects often seem less relevant to the larger issues and the great scale of the lakes. Create a priority plan within a long-term plan.”

“The LTR Program uses 64% (\$1.28 million) of the ECODYN science budget, leaving \$720,000 for other science projects. The majority of ECODYN funds come from the [Great Lakes] Restoration Initiative, meaning that the goals of the Restoration Initiative could be driving the majority of the other science work done by ECODYN, not the goals of GLERL. This is a problem. Other science areas under GLERL’s purview, that are not being addressed due to lack of personnel and base funding, but need to be addressed, are the understanding of future impacts of climate change to the Great Lakes ecosystem and coastal resiliency, fundamental research in biogeochemistry and the microbial food web, and modelling of water quality in important watersheds.”

“Create a longer-term strategy to broaden the work to be more inclusive of all the Great Lakes. Their models seem to focus on Lake Erie for HABs, but these issues are emerging in Lake Superior for example, and it would be nice to be/ahead of the game, especially given their ability to do this work.”

“Research on ecological mechanisms for HABs, hypoxia are important and they need to be further integrated into the models.”

“Most of ECODYN’s work occurs in Lake Michigan and western Lake Erie. Lake Michigan is totally within US waters and needed specific US monitoring. It was also technically the easiest lake to study for GLERL and it has many of the same problems as the other Great Lakes, especially Ontario and Huron. CSMI should have been broadening the research arena, however, we only heard of the work on dreissenid growth rates across the lakes. The fishery stakeholder wants GLERL to work more across the Great Lakes so that they could compare and contrast systems. Such comparisons would be informative. The development of food web models for each Great Lake should increase the presence of ECODYN in other Great Lakes and encourage their work with Fisheries Managers etc. in these other regions.”

“Determine if there is capacity to be more present in fisheries management.”

3. A critical problem within ECODYN is the age distribution of its scientists. This is because expertise is often only one person deep, and several older scientists may soon retire.



ECODYN leadership should intentionally transfer the wealth of knowledge and understanding amassed by older scientists to younger scientists/ new hires through planned overlap and mentoring. For positions that cannot be backfilled, ECODYN will become reliant on collaborations.

“... older scientists are highly productive and well respected, but they will retire soon. Their wealth of knowledge and understanding of the Great Lakes systems needs to be transferred. Some of that is happening now, with the new hires, but GLERL/ECODYN will be missing expertise in plankton ecology (zooplankton, some phytoplankton and the microbial loop), in fisheries and in food web modelling. Because expertise is only one person deep, some overlap and mentorship of new scientists in these fields would be beneficial.”

### **Integrated Physical and Ecological Modeling and Forecasting**

The Integrated Physical and Ecological Modeling and Forecasting (IPEMF) branch conducts innovative research and development of numerical models to predict the physical, chemical, biological, and ecological response of the Great Lakes due to weather, climate, and human-induced changes. The review panel’s overall ratings for IPEMF ranged from Satisfactory to Highest Performance.

#### *Quality*

Panelists who reviewed IPEMF discovered a small but effective team that includes researchers who are on par with the upper echelon of their peers in other federal labs and academia. Panelists consider IPEMF’s hydrodynamic modeling, meteotsunami work, water-wave-ice modeling, probabilistic water-quality modeling, and analysis of long-term water temperature data to be at the leading edge of research in these fields. The group publishes high-impact interdisciplinary modeling papers, but the number of papers has fallen from 2016 (46) to 2020 (28). This is believed to reflect the loss of several high caliber researchers. Panelists worry that without select hires to fill in lost or missing expertise there is a danger that model improvement will stagnate.

“IPEMF conducts innovative research and integrates information from other research groups and delivers on NOAA’s strategic goals, particularly on forecasting and nowcasting effectively. Their mission is to develop numerical models to predict the hydrodynamics and ecological responses in the Great Lakes. They have a small but effective team to study the impacts of hydroclimate, weather (eg. meteotsunamis), human induced changes ( eg. nutrient inputs) on lake processes in the Great Lakes, Lake Champlain and coastal Arctic. I am glad to see that they have continued and further developed their lake hydrodynamics, and net basin supply modeling work into a national water model framework, which are of very high quality.”

“Overall, IPEMF lead researchers are on par with the upper echelon of their peers in other federal labs and academia.”

“For more than 2 decades GLERL researchers have been leaders in hydrodynamic modeling. During the last 5 years, they have successfully migrated to a new modeling system, FVCOM [Finite Volume Community Ocean Model], that seems well-suited for multi-purpose uses in the Great Lakes. This has been implemented both for state-of-the-art operational forecasting, for process-based studies, e.g., meteotsunamis and exchange in the Straits of Mackinac and for coupled water-ice modeling. At a minimum, I believe the meteotsunami work and the water-wave-ice modeling are at the leading edge of research in their fields and will help to set the standard for operational forecasting of these important phenomena.”

“The lake hydrodynamics and water supply modeling continue to be an important foundation for science discovery in a directed range of topics and for satisfying specific stakeholder needs. Work on the very different topics of algal

blooms and of ice and under-ice states and fluxes are excellent items for IPEMF integration activities in the separate observations and modeling themes for these topics.”

“GLERL is well known for its ice monitoring efforts. During the last 5 years, valuable new analyses of these data have been accomplished that are enabling advanced seasonal ice forecasting. In addition, IPEMF researchers have made substantial progress on state-of-the-art water-wave-ice modeling both for application in the Great Lakes and for application in Alaska / the Arctic.”

“IPEMF research in the area of probabilistic water quality modeling is also at the leading edge of this field.”

“One of the marquee efforts by the OSAT group is their long-term water temperature data record. The recent analysis of these data by IPEMF to extract the climate signal is compelling and is commensurate with the leading research into the impacts of climate change on our Earth systems.”

“This group is continuing its high-quality lake research demonstrated in a high-impact publication in Nature—although the lead scientist is leaving GLERL. I am glad to see the process for refilling that position. In the Great Lakes ice modelling has not received significant attention in the past, but GLERL in collaboration with CILER [Cooperative Institute for Limnology and Ecosystems Research] developed a prediction system, which will have significant impact in the stakeholder community.”

“During my past review in 2016, I have highlighted that although the group is publishing high impact interdisciplinary modelling papers, it has lost researchers of high caliber in physical limnology, sediment dynamics and needs a physical oceanographer with this expertise to be competitive. Otherwise, there is a danger of stagnation on model improvement, for example, incorporating new knowledge in better lake parameterization schemes.”

“Production of peer-reviewed, open-literature papers has fallen from 46 in 2016 and 2017 to 31 in 2018 and 28 in 2020. Some variance is expected in these totals, but a possible explanation left unexamined by the lab was loss of key personnel such those from IPEMF. On direct questioning from the panel, the IPEMF leaders were able to say only that they hoped to have the opportunity to fill existing and anticipated openings. Additional details concerning how decisions would be made on whether to fill in the same science “slots” or to move to new areas also un-staffed at GLERL were not available to the panel.”

### *Relevance*

Panelists heard from a number of stakeholders regarding the ability of IPEMF research and operational products to directly meet their needs (for example, U.S. Coast Guard use of seasonal ice forecasts)—evidence of the high relevance of IPEMF’s work. Panelists viewed the transition of the Great Lakes Coastal Forecasting System (GLCFS) to the Great Lakes Operational Forecast System (GLOFS) as a major success, as did the Department of Commerce who awarded the team with the Bronze Medal for this successful transition. Some stakeholders informed the panelists that they would like for IPEMF products to transition to operations more rapidly, reflecting the extreme usefulness of the products.

“GLERL has built a strong stakeholder / user base both external and internal to NOAA. Much of this is based on the forecasts provided by the IPEMF group and is clear evidence of the high relevance of this group’s work.”

“Great Lakes water quality directly affects every citizen of the basin as well as the millions of visitors to the region through drinking water, industry, recreation, and the economy. IPEMF modelling for now- and forecasting of lake state, and climatic (long-term impacts) scenarios are very important in that regard. The research and operational products from this group are directly relevant to many stakeholders. Many people spoke highly of these activities, for eg: Coast Guard’s search and rescue, water levels coordination, outflow regulation etc. GLERL’s hydrodynamic models are being moved into operations at a timely scale, although some stakeholders want GLERL to speed up the process. GLERL has moved their hypoxia and HABs forecasting tools to operations, and they are proving to be very useful for decision-makers including public health officials, federal and state regulatory agencies, and water supply

(Toledo drinking water is one example). Also, GLERL's research on coupling lake models to the GCM/RCMs [Global Climate Models/Regional Climate Models] is important and expected to yield better climate impact studies in the future."

"Transition of the new FVCOM-based GLOFS to NOS is a major success. Adding 5-day ice forecasting is another substantial win. Coupling the lake forecast with NOAA's HRRR [High-Resolution Rapid Refresh] to improve lake effect snow forecasts is yet another important contribution."

"Additional highly important and highly relevant products that IPEMF has developed from its in-house research programs include seasonal ice forecasts, water quality forecasts in support of drinking water supply in Lake Erie, total water level prediction and flood & wave modeling in Lake Champlain."

"We heard from multiple external stakeholders how important GLERL forecast modeling is in the areas of coastal hazards, water quality, and ice conditions. The recurring request from stakeholders was for faster transition of GLERL/ IPEMF products into NOAA operational systems, due to their extreme usefulness."

"The stakeholders assembled for the review panelists – though not a random selection – were largely satisfied with the products they received. The one common concern was that GLERL and NOAA could not always be clear about how decisions were made for adding capabilities to existing "operational" models and whether and how stakeholders could have input to those decisions. Providing more information – some of it not under the control of GLERL but NOAA, I realize – would help integrate the most active stakeholders more closely in the important final stage of the "research to operations to research" pathway. Such integration could help inform lab directions for science discovery and for operational model development and applications either with or separately for particular stakeholders."

Relatedly, the 2016 review identified the need for institutionalizing the "science of going operational" for IPEMF, intending that this would give additional opportunities for staff to report progress in publications of one form or another at multiple interim stages of the process of moving research products from research to operations. That may have been done in the time between that review and this one, but it was not specifically identified for this panel. That idea remains a good one and its realization would also support the response to the need identified above for clearer statements of how research to operations to research can best be managed for the specific research and operations environments at GLERL."

"The lab's integrated modeling could be enhanced both for science discovery and for operational stakeholder satisfaction if stronger connections and use were made for modeled projections for future climate as drivers of change external to the processes already represented in many of the IPEMF products. Other NOAA labs, centers, and institutes are very well placed and resourced to provide both projected future outputs and recommendations for using them to condition and constrain effects models of the sort that GLERL develops and applies. Additional close contact and development of this intra-NOAA resource would be beneficial."

"Researchers in this group have been active in GLWQA binational committees, such as adaptive management (Annex 4) and science (Annex 10). Another area that may require GLERL expertise is in Annex 9, for better GCM predicted climate variables for the basin."

### *Performance*

Panelists who reviewed IPEMF thought the staff were doing a better job of integrating work and products from OSAT and ECODYN compared with the last review. Panelists also found that IPEMF has and continues to successfully transition models/ products to other operational parts of NOAA (particularly NOS). Clear hand-offs of responsibility and effort are necessary for IPEMF staff to redirect to new activities. Formal transition plan agreements between the developer (GLERL) and operator (NOS) are signed at project initiation to facilitate this hand-off. Several such plans were shared with the review panel. Some stakeholders expressed concern that NOAA/ GLERL is not always clear about how decisions are made for adding capabilities to existing

‘operational’ models. External stakeholders wanted to know whether and how they could contribute to such decisions. Panelists were happy to learn of progress related to data management and commend GLERL for recognizing its importance and providing the necessary resources. The next step is to develop reproducible data-model workflows that would create efficiencies for IPEMF modelers.

“The IPEMF work presented for review is fully satisfactory. The IPEMF staff are incorporating many of the recommendations in the 2017 GLERL review that pointed to the need for better integration across work and products from the other two lab branches to fulfill the “integrated” potential of this branch. This is a good development.”

“Congratulations to the Director, GLERL and her IPEMF team for exceptional performance during this review period. Since its inception, GLERL has developed a good reputation in the region and they work very effectively with users for disseminating their products, and I am glad to see that is still the focus of this group. IPEMF has demonstrated that they have a clear plan on enhancing their research models under Dr. Chu’s leadership, for eg: R2O plans such as migration of FVCOM to operations in all Great Lakes.”

“The nature of a review is to focus on the successful, high visibility activities, of which IPEMF has a substantial portfolio. As such it is difficult to identify substantial areas to abandon in favor of other more promising efforts. That being said, it is clear that IPEMF has and continues to successfully transition models / products to operational parts of NOAA (particularly NOS). It seems important that as these transitions occur, there is a clear hand-off of responsibility and effort (at the appropriate time), allowing IPEMF staff to redirect their time and efforts to new activities, rather than continuing to run the same modeling systems in house in parallel with the operational runs. Otherwise, the IPEMF plate will get fuller and fuller, undoubtedly slowing down progress on new efforts. It was difficult during the review to ascertain to what degree this was an issue and therefore I raise this as mostly a cautionary suggestion.”

“Clearly there are gaps in staffing, for eg: a physical limnologist (or physical oceanographer) with a focus on mixing characteristics and sediment dynamics is needed to further develop GLERL’s innovative modelling work.”

“The ecological forecasting is naturally a good extension of the core work of this group. Dr. Chu mentioned that by design the ecosystem modeler is placed in the ECODYN group and that modeler participates in IPEMF meetings and acts as a bridge between the 2 divisions. I think this is a good approach.”

“One issue that I noticed is that GLERL did not demonstrate the model skill assessment in their presentations, this is one area that needs continuous data or partnerships.”

“In my opinion the research productivity and the product transition are at a very high level given the size of the IPEMF group. While these successes are clustered in a few sub-areas, there is considerable evidence of collaboration across the IPEMF group, with other groups within GLERL, with CIGLR and with groups outside of NOAA.”

“GLERL management should encourage staff to participate in broader networks with universities and with Canada, otherwise their research is limited to a few lakes, and a bit repetitive.”

“I was impressed by the inclusion of dedicated data management within IPEMF, for the benefit of all groups at GLERL. Data management, e.g. as outlined in FAIR principles, is often left to the research scientists to perform, is usually under-resourced and thus is often poorly done. Recognition of the importance of this effort and dedication of resources for this purpose is commendable.”

“IPEMF also made a good effort in data management/dissemination systems, which is a key to the success of this group.”

### *Actionable Recommendations*

1. IPEMF is responsive to feedback on their research models from internal stakeholders at NOS, but external stakeholders (for example, U.S. Army Corps of Engineers) are not clear on the process for communicating their requirements. IPEMF/ ECODYN should develop a clear communications plan describing the ‘research to operations to research’ pathway for models and share it with key internal and external stakeholders.

“The process during the transition to operations, needs a clear communication plan. During the phase, the responsibilities of different departments/agencies may be less well known and defined, and better communication would help stakeholders feel kept in the loop and less likely to misunderstand or misrepresent GLERL’s role.”

“Not all stakeholders shared the same understanding of how to interact with GLERL staff to provide feedback, and interactions seemed to rely on who you knew at GLERL. This is fine except that as there is staff turnover, both among GLERL and stakeholders, new relationships need to be built, which can affect communication. For example, some stakeholders perceived that GLERL was responsible for delays in the transition to operations whereas it is possible that factors unrelated to GLERL and in other aspects of NOAA infrastructure, are the reason for the delays. It would be nice if at least these stakeholders could remain updated on processes like this.”

2. The IPEMF staff works on assorted topics of great importance with an eye toward an integrated Great Lakes modeling system. IPEMF should clearly identify priority process-based research topics to be pursued during the next 5 years in the GLERL 2021-2025 strategic and implementation plans. The extent that these require participation from OSAT and ECODYN should be described. Topical areas that seem well-suited for additional process-based research include, (1) effects of climate on the Great Lakes, including the feedback that climate-induced changes in the lakes will have on the future climate, (2) processes controlling long-term lake levels, and (3) water-wave-ice dynamics.

“I was pleased to see the IPEMF actively considering the effects of climate on the Great Lakes in multiple areas, including water temperature and ice cover. I encourage this to continue as a major area of research (as is identified in the 2021-25 strategic plan).”

“Given their size and volume, I wonder about the feedback that climate induced changes in the Great Lakes will have on the future climate? There was some indication of work in this area, perhaps in collaboration with GFDL [Geophysical Fluid Dynamics Laboratory], but it wasn’t well described, and it doesn’t seem to show up in the 2021 - 25 strategic plan. This might be an area for additional focus.”

“There seems to be several very high-profile issues in the Great Lakes that have served as foci for GLERL research activities, e.g., ice, invasive species, HABs/drinking water quality, operational forecast modeling. While not all of the valuable work going on at GLERL addresses these topics, they arguably rise above the others in their significance (I apologize if I missed something). I’d place long-term lake water levels in this same high-profile issue category. GLERL clearly recognizes this as an important topic and it is a stated justification for ongoing activities, e.g., coupling the NWM with the GLOFS. However, I believe it would be helpful to have a specific focus on the degree to which the processes controlling the long-term lake levels are understood and can be predicted into the future (considering climate change, development, management decisions, etc). In the 2021-25 GLERL strategic plan, the forecast/prediction objectives / outcomes are quite broad (realistically, they encompass virtually all aspects of earth system modeling and forecasting) and thus don’t elevate the long-term lake levels above any of these other areas. I would reconsider that.”

“I only saw the word “ice” show up in one place in the 2021-25 Strategic Plan Appendix C - Implementation Plan, in which it was included in the list of all things included in a coordinated Great Lakes modeling system (Objective 3.1). I assume ice related research will continue to be a focal area of GLERL/ IPEMF activities both in the Great Lakes and more broadly in other areas? If so, I strongly encourage a better identification of this work in this plan.”

3. Given IPEMF's long range goal of an integrated Great Lakes modeling system, it is imperative that work begin now to develop a set of tools to configure data access, transfer data directly to models, and then run those models. *IPEMF should connect with the broader interagency modeling community and develop reproducible data-model workflows that will create efficiencies to free up modelers' time for other activities.*

"Working to reduce the backlog of data that have yet to be made available online is a huge step forward for GLERL. To date, data that go along with publications have been the focus on this effort. Equally important, however, are reproducible data-model integration workflows that could free up more time for the modelers. At present, it seems as though modelers (and stakeholders) separately prepare data for their own models, potentially resulting in duplication of efforts. Improving these types of workflows has garnered interagency attention at the national scale in recent years (see the workflow section of the following report [https://data.pnnl.gov/sites/default/files/2020-09/IHTM\\_Workshop\\_Report\\_FINAL\\_0.pdf](https://data.pnnl.gov/sites/default/files/2020-09/IHTM_Workshop_Report_FINAL_0.pdf)). IPEMF would be wise to connect with these other agencies and advance its data-model workflows over the next five years."

## Summary of Recommendations

**LABWIDE.1.** Host a special all hands meeting to explain how NOAA facilities funds are procured and describe how OAR/ GLERL have been working to try and replace Building 3 at the Lake Michigan Field Station.

**LABWIDE.2.** Continue to improve internal communications with a focus on opportunities for upward communication (for example, use of the Round Robin Method to encourage everyone to ask questions during meetings).

**LABWIDE.3.** Develop a staffing plan that identifies the optimal mix of government, contractor and CIGLR staff to maximize retention and increase lab stability and then work toward that goal.

**LABWIDE.4.** Identify the work GLERL definitely needs to be doing in the long-term and support it with base funding even if it means completing and (or) stopping some ongoing work.

**LABWIDE.5.** Include the following in the 2021-2025 implementation plan:

- milestones across the entire duration of the strategic plan,
- timeframes for transitioning research to operations/ applications, or for ending work altogether, to facilitate starting higher priority work, and
- a graphical lab-wide roadmap(s) that identifies interdependencies among the research themes to help ensure lab-wide, as opposed to project-specific, science integration.

**OSAT.1.** Clarify the role of curiosity driven research within OSAT and follow through with an appropriate level of support.

**OSAT.2.** Establish observing systems more uniformly across all five lakes.

**OSAT.3.** Develop a formal process for internal and external stakeholders to communicate future data and technology requirements and share the process with stakeholders.

**ECODYN.1.** Initiate more collaborations with Canadian scientists (and others outside the Great Lakes) to broaden the scope of the research performed.

**ECODYN.2.** Develop a long-term research plan (5-10 years) that includes key research questions and create a priority plan within that plan to inform near-term research investments; planning should be inclusive of all Great Lakes.

**ECODYN.3.** Intentionally transfer the wealth of knowledge and understanding amassed by older scientists to younger scientists/ new hires through planned overlap and mentoring.

**IPEMF.1/ ECODYN.4.** Develop a clear communications plan describing the ‘research to operations to research pathway’ and share it with key internal and external stakeholders.

**IPEMF.2.** Identify priority process-based research topics to be pursued during the next 5 years in the GLERL 2021-2025 strategic and implementation plans. Topical areas that seem well-suited for additional process-based research include, (1) effects of climate on the Great Lakes, including the feedback that climate-induced changes in the lakes will have on the future climate, (2) processes controlling long-term lake levels, and (3) water-wave-ice dynamics.

**IPEMF.3.** Connect with the broader interagency modeling community and develop reproducible data-model workflows that will create efficiencies to free up modelers’ time for other activities.

## Glossary

AEP - Annual Execution Plan

AUV - Autonomous Underwater Vehicle

CIGLR - Cooperative Institute for Great Lakes Research (formerly CILER)

CILER - Cooperative Institute for Limnology and Ecosystems Research

CPA-A - Color Producing Agent Algorithm

CSMI - Coordinate Science and Monitoring Initiative

DART - Deep-Ocean Assessment and Reporting of Tsunamis buoy

DOC - Department of Commerce

ECODYN - Ecosystems Dynamics

ECCC - Environment and Climate Change Canada

FAIR - Findability Accessibility Interoperability Reuse

FVCOM - Finite Volume Community Ocean Model

GCM - Global Climate Model

GFDL - Geophysical Fluid Dynamics Laboratory

GLCFS - Great Lakes Coastal Forecasting System

GLERL - Great Lakes Environmental Research Laboratory

GLEON - Global Lake Ecological Observatory Network

GLOFS - Great Lakes Operational Forecast System

GLOS - Great Lakes Observing System

GLEON - Global Lake Ecological Observatory Network

GLRI - Great Lakes Restoration Initiative

GLWQA - Great Lakes Water Quality Agreement

GOOS - Global Ocean Observing System

HAB - Harmful Algal Bloom

HRRR - High-Resolution Rapid Refresh

IPEMF - Integrated Physical and Ecological Modeling and Forecasting

LTR - Long-Term Research program

MBARI - Monterey Bay Aquarium Research Institute

MOCNESS - Multiple Opening and Closing Environmental Sensing System

MTS - Marine Technology Society

NDBC - National Data Buoy Center

NOAA - National Oceanic and Atmospheric Administration

NOS - National Ocean Service

NWM - National Water Model

OAR - Office of Oceanic and Atmospheric Research

OSAT - Observing Systems and Advanced Technology  
PI - Principal Investigator  
R2O - Research to Operations  
RCM - Regional Climate Model  
ReCON - Real-Time Coastal Observation Network